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Past echolocation research (Schusterman and Kersting, 1978) demonstrated control over the dolphin's echolocation emissions in a binary (on/off) condition. The dolphin performed a discrimination task while its echolocation output was under stimulus control of an underwater tone. The animal learned to echolocate during the presence of the tone and to remain silent if no tone was given.

Mackay used two Atlantic bottlenose dolphin (*Tursiops truncatus*) to determine the dolphin's capability to control whistle emissions in the 5-16 kHz range. Using automatic feeders activated by specific frequency ranges, Mackay showed that dolphins could control the frequency of their whistles.

Recent research revealed behavioral control can also be obtained over the source level of the echolocating dolphin. Moore and Patterson trained a dolphin to perform a detection task while under operant control of its emitted source levels.

Dolphin clicks are short duration (10 to 100 microsec) wide band transients. It is thought that the target, to a large extent, dictates the click emission parameters of frequency and amplitude. Past research shows that dolphins control the repetition rate of emitted clicks as a function of target range, but the capability of the dolphin to independently control both the frequency and source level of their clicks has never been demonstrated.

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COMBINED STIMULUS CONTROL OF PEAK FREQUENCY AND SOURCE LEVEL IN THE ECHOLOCATING DOLPHIN (*Tursiops truncatus*)

by

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INTRODUCTION

Past echolocation research (Schusterman and Kersting, 1978) demonstrated control over the dolphin's echolocation emissions in a binary (on/off) condition. The dolphin performed a discrimination task while its echolocation output was under stimulus control of an underwater tone. The animal learned to echolocate during the presence of the tone and to remain silent if no tone was given.

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Dolphin clicks are short duration (10 to 100 microsec) wide band transients. It is thought that the target, to a large extent, dictate the click emission parameters of frequency and amplitude. Past research shows that dolphins control the repetition rate of emitted clicks as a function of target range (1972; Au et al, 1982), but the capability of the dolphin to independently control both the frequency and source level of their clicks has never been demonstrated.

EXPERIMENTAL DESIGN

The test subject was a 19 year old male Atlantic bottlenose dolphin (<u>Tursiops truncatus</u>) designated Tt-622. The dolphin weighed 211.8 Kg with a body length of 277.8 cm by the end of the three year study. Over the course of the experiment, the dolphin gained 45 kg and grew 17.8 cm in body length.

The dolphin is housed in floating ocean pens located in Kaneohe Bay, Hawaii. Located on the deck of the test pen is an instrument shelter which housed the electronic equipment used to measure the dolphin clicks.

The dolphin stationed at a fixed point facing the electronics room during inter-trial intervals. This additional control demonstrated improved learning in past dolphin research (Herman and Arbeit, 1973). From this station, the dolphin is sent to a bite-plate/ tail-rest assembly located one meter below surface level and facing away from the trainer. The acoustically transparent bite-plate insured accurate click evaluation by positioning the dolphin's nasal sac region directly in line with the collecting hydrophone. Stimuli and reinforcer tones originated from the same Apple IIE computer system that collected and analyzed clicks via an underwater hydrophone (Ceruti and Au, 1983). The trainer initiated the amplitude tone superimposed with the frequency interruption rate for 3-5 seconds while the dolphin settled into a straight, stationary position on the bite-plate [illegible] assembly.

The screen is lowered out of position between the dolphin and the hydrophone, signaling the dolphin to emit clicks. The trial time is limited to three seconds. After an incorrect

response, the stimulus tone is terminated and the screen raised into position. When the dolphin emitted clicks of correct frequency and amplitude, the computer-controlled reinforcer tone immediately sounded underwater. The dolphin reacted instantly by surfacing for his fish reward. A fifty trial session averaged 45 minutes in running time.

TRAINING PROCEDURES

The first step of amplitude training is the general concept of "shout" or "whisper", and the dolphin mastered the task quickly. Once the animal learned to shift his amplitude up and down in separate sessions, it required less than sixty sessions, using blocks of high or low amplitude trials, before the dolphin exhibited stimulus control in a random presentation of trials.

Bimodal frequency output is the simultaneous occurrence of high relative energy at opposite ends of the frequency range (Fig. 1). Bimodal frequency output was immediately observed in high amplitude trials. During trials of average (200 dB) amplitude, the frequency spectra of the dolphin's clicks was either broadband (relatively flat across the frequency range), low frequency (major energy in the 30-60 kHz range) or high frequency (major energy in the 105-135 kHz range). But in trials with amplitude levels above 200 dB, the relative energy output elevates in both low and high frequency ranges (bimodal), with minor energy output in the median range. Bimodal output, although noted for the record, was disregarded at this stage of training. Amplitude output and its control were the primary objectives at this time.

Early training incorporated simple target detection sessions into amplitude training sessions. The detection sessions remained separate as a means to get click emission and stable performance. Subsequent sessions imposed an amplitude criterion onto the working dolphin that steadily increased in difficulty as performance improved in the amplitude task.

Target detection and amplitude control sessions successfully combined into a single task after seven sessions (350 trials) of alternate blocks of detection or amplitude trials. The dolphin maintained performance above 90% for the combined amplitude and detection criteria when presented with both tasks in a random series.

Control over the amplitude, simultaneously with frequency output, was the training objective. The dolphin typically used clicks of 200 dB for detection work before any training in amplitude control. Faced with frequency criteria, the dolphin shifted its amplitude when the correct response would be a change in frequency. High amplitude clicks (with inherent bimodal output) were of interest, so the chosen amplitude criteria to incorporate into the frequency trials was >195 dB. The high amplitude tone, with the repetition rate of the selected frequency stimuli super-imposed over it, achieved both amplitude control and frequency control simultaneously. The amplitude variable was now eliminated and training centered on frequency control.

Frequency training in the high amplitude range required a criterion design limiting the amount of bimodal output in the

energy spectra of the emitted clicks. Progressive program modifications shaped the dolphin's output until the desired click parameters were met.

A program designed to limit the amount of bimodal (incorrect) frequency output to 75% of the criterion (correct) output was successful in reducing bimodal click emissions. This design checked the highest output in the opposing (incorrect) frequency range and allowed it to be up to 75% of the total energy emitted in the highest bin of the correct range.

A final stage of testing was conducted to investigate the effect of bite-plate composition of the ability to control emitted frequency. Neoprene of 1/8" thickness, layered on the top and bottom face of a identical bite-plate, was used in the frequency control testing situation. The assumption was that the air-filled neoprene would tend to isolate the upper head (the assumed sight of click production) from the lower jaw (the presumed sight of click reception). This isolation could possibly reduce acoustic coupling between the click source and the lower jaw, thereby reducing the acoustic intensity of the animal's emissions. This could allow the animal to hear its generated clicks better. Possible interference to the lower jaw from the click source located above the jaw would be blocked by the reflective quality of the neoprene.

Eight sessions with random use of bite-plate types were completed for comparison. The results indicated an amplifying effect of the reflected low frequency clicks from the lower jaw area. With the neoprene-covered bite-plate, overall amplitude

levels of both high and low frequency trials are similar ($\pm$ 3 dB) as compared to the previous tests with the polystyrene bite-plate which showed a 13 dB difference. High frequency clicks were slightly lower in amplitude and low frequency clicks were higher in amplitude, while both maintained excellent frequency spectra as displayed in Fig. 6.

CONCLUSIONS

The training of frequency control is very specific in comparison to the training of an amplitude control task in the echolocating dolphin. The dolphin exhibits the ability to change the frequency content of its clicks instantly (click-by-click), and can produce clicks with dual energy peaks in widely separate frequency ranges (bimodal).

Dolphins are also capable of simultaneous independent control of the frequency and amplitude of their echolocation clicks in response to conditioned cues for such behavior.

LITERATURE CITED

Au, W.W.L., Penner, R.H., and Kadane, J., 1982. Acoustic behavior of echolocating Atlantic bottlenose dolphins. Jour. Acoust. Soc. Am., 71, 1269-1275.

[illegible], M.S. and Au, W.W.L., 1983. Microprocessor-based system for monitoring a dolphin's echolocation pulse parameters. Jour. Acoust. Soc. Am., 73, 1390.

Herman, L. M. and W. R. Arbeit, 1973. Stimulus control and auditory discrimination learning sets in the bottlenose dolphin. Jour. Exp. Anal. Behavior., 19, 379-394.

Mackay, R. S., 1981. Dolphin interaction with acoustically,

controlled systems: aspects of frequency control, learning, and non-food rewards. Cetology, 41.

Moore, P. W. B., and S. A. Patterson, 1983. Behavior control of echolocation source level in the dolphin (*Tursiops truncatus*). presented at the Fifth Biennial Conference on the Biology of Marine Mammals (Boston, MA).

Schusterman, R. J., and D. A. Kersting, 1980. Stimulus control of echolocation pulses in *Tursiops truncatus*. IN: Animal Sonar Systems. R.-G. Busnel and J. Fish, eds. Plenum. pp.981-982.

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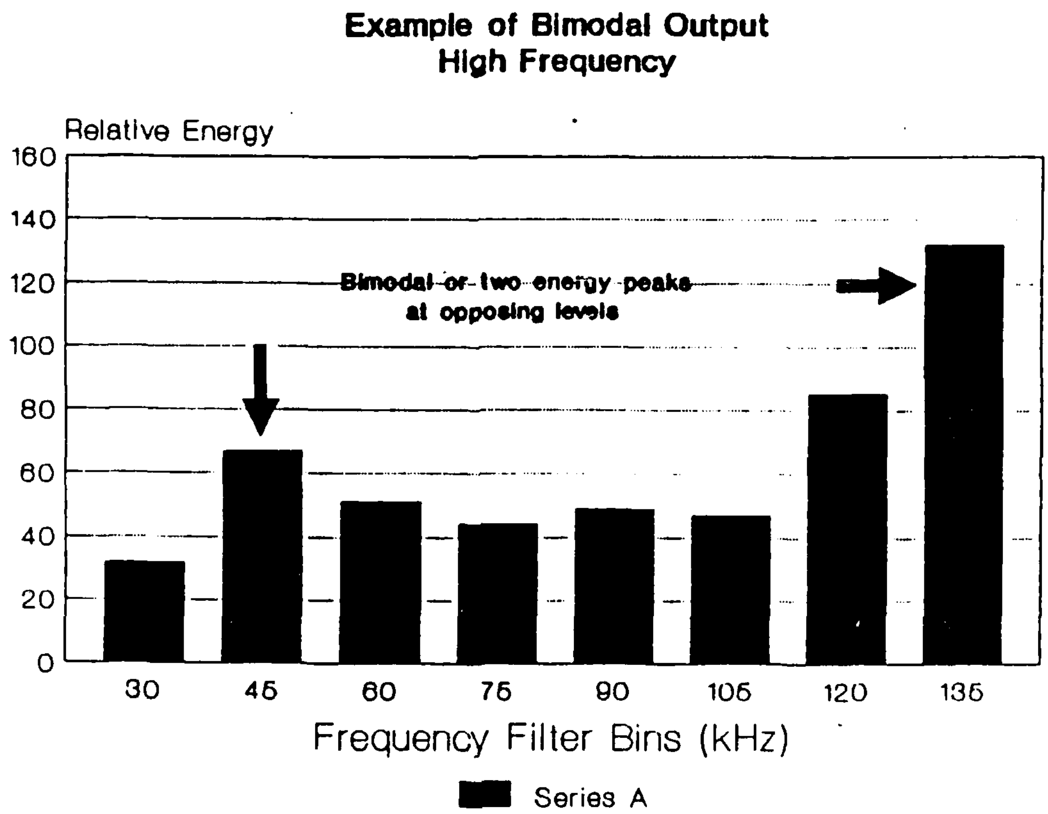

During 95% performance levels

Figure 1.

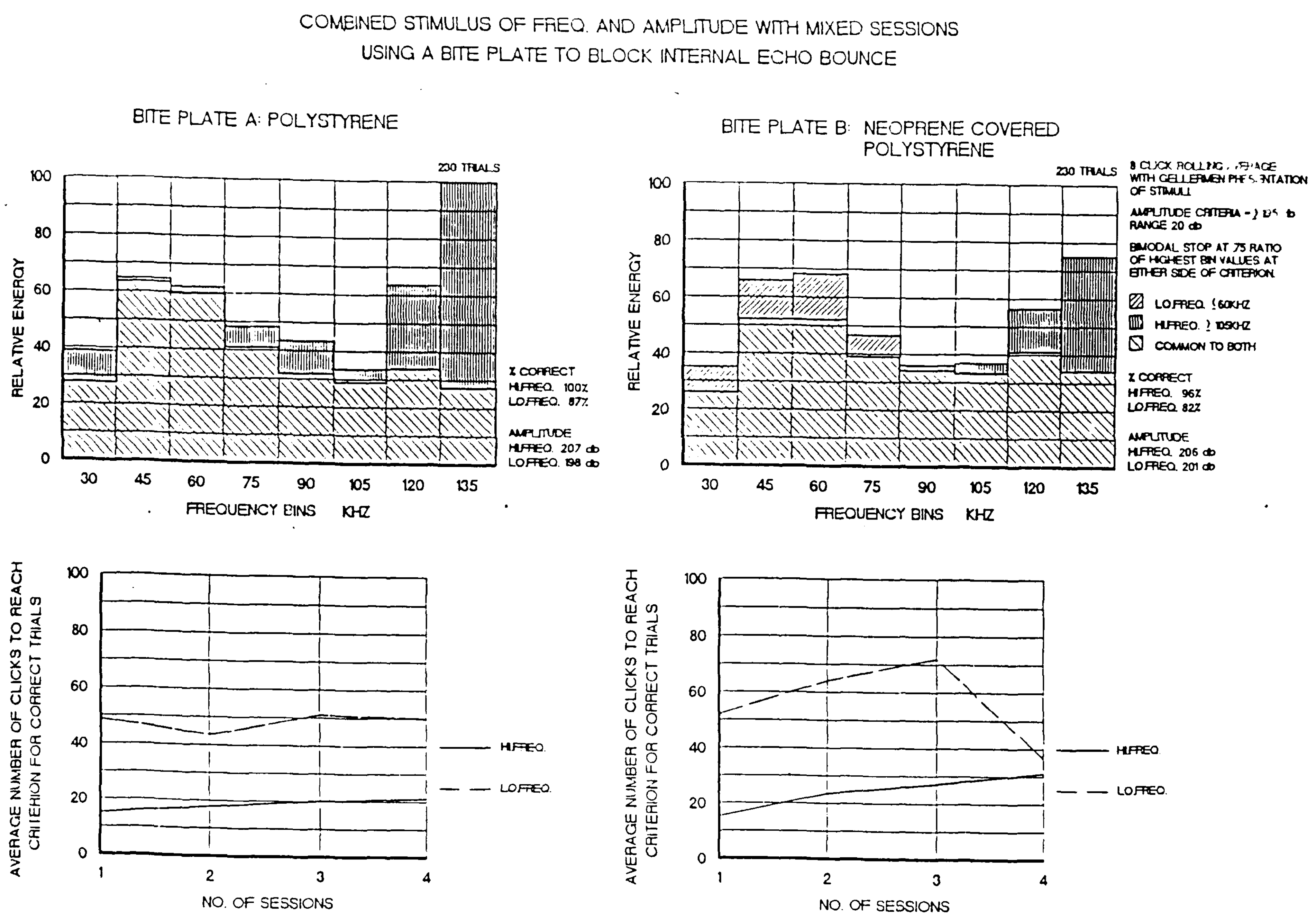
COMBINED STIMULUS OF FREQ. AND AMPLITUDE WITH MIXED SESSIONS
USING A BITE PLATE TO BLOCK INTERNAL ECHO BOUNCE
BITE PLATE A: POLYSTYRENE
230 TRIALS
RELATIVE ENERGY
FREQUENCY BINS KHZ
% CORRECT
HI FREQ. 100%
LO FREQ. 87%
AMPLITUDE
HI FREQ. 207 db
LO FREQ. 198 db
BITE PLATE B: NEOPRENE COVERED POLYSTYRENE
230 TRIALS
OF STIMULI
RANGE 20 db
BIMODAL STOP AT 75 RATIO
OF HIGHEST BIN VALUES AT
EITHER SIDE OF CRITERION
COMMON TO BOTH
% CORRECT
HI FREQ. 96%
LO FREQ. 82%
AMPLITUDE
HI FREQ. 206 db
LO FREQ. 201 db
AVERAGE NUMBER OF CLICKS TO REACH CRITERION FOR CORRECT TRIALS
NO. OF SESSIONS
HI FREQ.
LO FREQ.

Figure 2.